COAL MINE SOIL AND OVERBURDEN SURVEYS AND RECLAMATION PLANNING[1]

by

A. Schori[2], W.J. Hastie[3], D.K. McQueen[2], G.V. Minning[4] and E.C. Wenzel[2]

Abstract. The Highvale Mine, located in Central Alberta approximately 65 km west of Edmonton, is one of several large coal strip mines presently operated in agricultural areas of Alberta. Government guidelines require that mined land be returned to a capability equivalent to pre-mine conditions. Detailed soil and overburden surveys were conducted at the Highvale Mine in 1984-85 for areas to be mined in the 25 year period, 1986 through 2011. Soil survey information collected from approximately 1500 field inspections was used to: document the distribution, morphology and chemical/physical properties of soils; determine land capability for agriculture (CLI); determine soil suitability for reclamation; and provide a data base for surface soils. A total of 448 drillholes were completed to determine overburden thickness and to collect samples. Chemical and physical data from drillhole samples were used to describe properties of principal overburden units and to rate overburden materials for reclamation suitability. Information from the soil and overburden programs was integrated to optimize materials handling efficiency and achieve reclamation objectives.

Additional Key Words: subsoil, soil capability, soil suitability, reclamation planning, geographic information system.

Introduction

Strip mining of coal involves the removal of soil and overburden which lies above the coal and then extracting the exposed coal. Mining and reclamation are now generally more or less integrated. Topsoil, and often also subsoil, are removed prior to mining with scrapers. These materials are then stockpiled for subsequent use or, if possible, placed directly on levelled mined land.

Reclamation problems result from the nature of the overburden materials and the method of mining. The overburden which occurs over the coal is often soft bedrock of later Cretaceous age with chemical and physical characteristics adverse to plant growth. Strip mining with draglines results in material from the surface being placed

[1] Paper presented at the conference Reclamation, A Global Perspective, held in Calgary, Alberta, Canada August 27-31, 1989.
[2] Senior Supervising Soil Scientist; Senior Soil Scientist; Senior Engineer Technologist (respectively); Monenco Consultants Ltd., Calgary, Alberta, T2P 3W3
[3] Supervisor, Reclamation and Farm Services, TransAlta Utilities Corporation, Calgary, Alberta, T2R 0G7
[4] Geologist, GVM Geological Consultants Ltd., Calgary, Alberta

Proceedings America Society of Mining and Reclamation, 1989 pp 579-588
DOI: 10.21000/JASMR89020579
https://doi.org/10.21000/JASMR89010579

in the bottom of the pit and the deeper material ends up at the surface. The sequence of strata are therefore reversed, with the undesirable overburden at the surface. This material is often extremely sodic with a very high sodium content and has a high proportion of swelling clays (Schori, 1985).

In Alberta, provincial government policy requires that "... disturbed land will be returned wherever possible to a state that will support plant or animal life or be otherwise productively useful to man, at least to the degree it was before it was disturbed" (Coal Development Policy 1976). Alberta Government Regulations and Guidelines also require that appropriate soil salvage and replacement be carried out so that reclaimed land will have a land capability equal to that which existed prior to mining. In order to meet these government requirements, appropriate data regarding the nature and extent of soils and overburden in the pre- and post-mining environments is required.

Surface coal mining at Highvale, about 65 km west of Edmonton, began in 1971. To date, coal has been removed from four pits within the Highvale Mine permit area. The pits are located along the south side of Lake Wabamum in a 16 km long, 6560 ha band from east to west (Figure 1). Mining in each pit commenced near the lake and has proceeded southward over time. TransAlta Utilities Corporation's Highvale Mine supplies about 12 million tonnes of coal per year to the Sundance and Keephills thermal power plants,

Reclamation experience over the past few years at Highvale indicated that some reclaimed areas do not have good soil tilth. TransAlta therefore reviewed the soil suitability for reclamation criteria and recommended modifications.

The following discussion outlines the generation and interpretation of soil data for mine planning and reclamation at the Highvale Mine.

Methods

Reclamation planning for subsoil handling has evolved as a multi-disciplinary task involving pedologists, geologists and mining engineers. Standard pedology and surficial geology survey techniques and laboratory analyses were conducted. Soil and overburden information was then integrated to refine suitable subsoil distribution patterns, spatially and vertically.

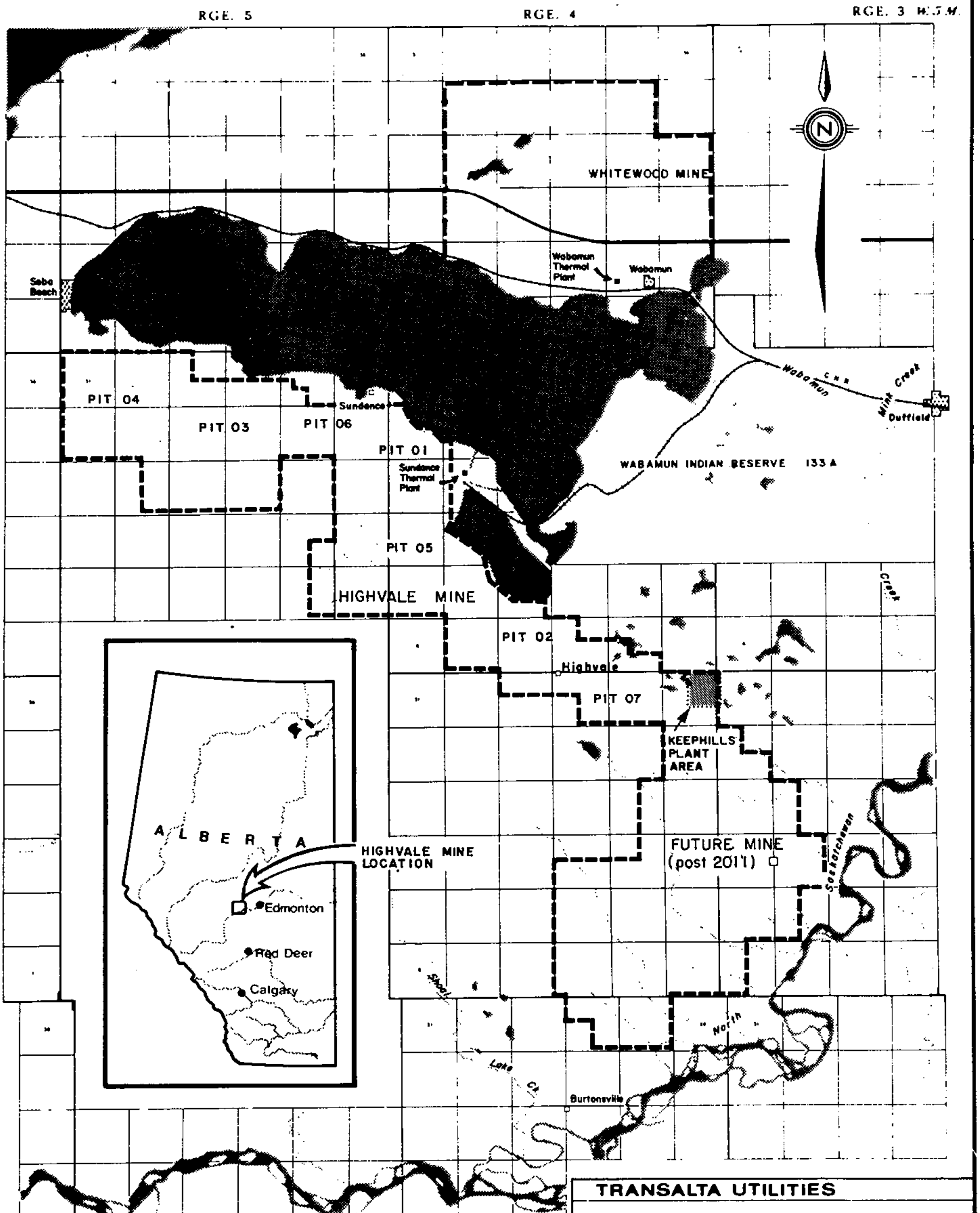
Subsoil handling was optimized using mine plans combined with information on soil volumes (annual replacement requirements and availability) from the baseline soil survey map and end land use plans.

This section outlines the methods used in conducting the soil survey, overburden survey, laboratory analyses (soils and overburden), suitability rating, survey data integration and materials handling optimization.

Surveys

Soil Survey. The soil survey was conducted in 1985 (Monenco Ltd., 1986). Pits 02, 03 and 04 were surveyed at survey intensity level 1 (SIL 1), with one field inspection per 10 ha. Pits 05 and 06 were surveyed at SIL 2, with one field inspection per 10 ha. Soil maps were produced at a scale of 1:10,000.

Approximately 1,500 field inspections were made. These inspections included: 37 soil pits described in detail and sampled; 650 inspections included exposing A and B soil horizons with a shovel, to determine soil structure, and hand augering to one metre; and approximately 800 inspection sites were hand augered to the C horizon (parent material) or to 1 m. Approximately 10% of the inspection sites were sampled. All the site locations were recorded.



TRANSALTA UTILITIES

PROJECT LOCATION PLAN

MONENCO LIMITED

89·08·27 DATE	MEB 7967-2 WORKORDER 890001 SUBCODE SYSTEM	FIGURE 1

Field data sheets were completed for each site.

Soils were classified according to the Canadian System of Soil Classification (Canadian Soil Survey Committee 1978). Soils were described as per the Canada Soil Information System Manual (Day, 1983). Twenty-six soil series were described and named according to the Alberta soil series conventions.

The soils were rated for agricultural capability according to Canada Land Inventory Guidelines (Brocke, 1977). The system groups mineral soils into seven classes according to their capability for agricultural use. Classes 1 to 3 are capable of sustained production of common cultivated crops; class 4 is considered marginal for cultivation; Class 5 is capable for only permanent pasture or hay; Class 6 is capable for native grazing and Class 7 has no capability for agricultural use. Organic soils are not rated.

Overburden Survey. An overburden drilling and sampling program was conducted during the period 1984 to 1986 in Pits 02 through 07. The program was conducted at two levels of intensity: detailed - 1 drillhole per 4 ha (200 m grid); and reconnaissance - 1 drillhole per 64 ha (800 m grid). Table 1 presents a summary of the drilling and sampling intensity by individual pit. The detailed drilling was required in areas currently under development. The reconnaissance was carried out in areas to be mined in future (i.e. not for at least 5 years).

A total of 448 drillholes were completed. Sixty-two drillholes penetrated coal and were drilled by a reverse circulation drill rig. An auger rig drilled the remaining 386 drillholes to auger refusal. A total of 4311 samples were examined (stratigraphy, lithology, thickness, color, texture, plasticity, consistence)and 1770 samples were collected for laboratory analyses.

TABLE 1

Summary of Soil and Overburden Inspections and Sampling

Mine Pit Number	Area (ha)	Inspection Density	Overburden Number of Drillholes	Soil Number of Sites Inspected	Soil Number of Sites Sampled
Pit 02	506	detail	122	313	38
Pit 03	832	detail	143	425	50
Pit 04	809	detail	141	637	69
Pit 05	308	reconnais.	13	50	14
Pit 06	209	reconnais.	18	59	16
Pit 07	N/R	reconnais.	11	4	4
Total	2664		448	1478	191
Number of Samples Analyzed			1770		433

N/R - Not Reported (area to be mined after 2011)

Geophysical logging of the reverse circulation drillholes was carried out to aid correlation of auger and reverse circulation drillholes, in order to prepare overburden cross-sections. The logging package included natural gamma ray, long-spaced side wall density, bed resolution density, caliper, dual-spaced neutron and focussed electric.

Laboratory Analyses

An extensive analytical program was conducted by Monenco Analytical Laboratories to chemically and physically characterize the soil and overburden materials. Methods of analysis are presented in Table 2.

A quality control program, using standard check samples from the Highvale area, was also conducted by the laboratory.

Soil Analyses. Chemical and physical analyses were conducted on 433 samples.

Overburden Analyses. Samples (1770) were analyzed to determine chemical and physical parameters of the 10 major stratigraphic units. The parameters included: grain size (% sand, silt and clay); pH; EC; SAR; % ESP; CEC; and saturation %.

Reclamation Suitability Ratings

Both the subsoil and overburden materials were rated for reclamation suitability. Topsoil was not rated as all topsoil is considered suitable for salvage and replacement.

Subsoil Suitability Ratings. Subsoil suitability criteria, shown in Table 3, are as per. Alberta Soils Advisory Committee (1981) with some modifications. Local reclamation experience showed that modifications were necessary to reflect the combined effect of marginally adverse physical and chemical characteristics.

TABLE 2

Laboratory Analysis

Parameter	Method[a]	
Physical		
grain size (sand, silt, clay)	(3 point hydrometer)	2.12
saturation %		3.21
pH	(of extract)	3.21
electrical conductivity	(of extract)	3.21
organic carbon[b]	(mod. Walkley-Black)	3.613
Chemical		
soluble cations, SAR	(Ca, Mg, Na, K)	3.26
cation exchange capacity		3.321B/3.34
exchangeable cations[c]	(Ca, Mg, Na, K)	3.321A

(a) reference: McKeague, 1978.
(b) topsoil (Ap, Ah, Ahe) horizons of detailed pits only.
(c) subsoil (B) horizons - where SAR is greater than 8 and/or EC is greater than 2; and from selected B horizons with columnar or prismatic structure.

Four categories of subsoil suitability were developed (TransAlta Utilities Corporation, 1986).

Category 1 - Solonetzic Soils and fine textured Gleysolic Soils (no suitable subsoil). The B and C subsoil horizons of the Solonetzic soils are unsuitable for reclamation due to heavy clay textures, columnar to blocky structure, very hard consistence when dry, and high SAR and ESP values. The B and C subsoil horizons of the Gleysolic soils are unsuitable due to clay and heavy clay textures and very sticky consistence.

Category 2 - Fine Textured Luvisolic Soils (shallow suitable). The B horizons are suitable subsoil for reclamation. They are non-sodic, with silty clay to clay texture, blocky structure and sticky (wet) to hard (dry) consistence. These properties are expected to provide manageable subsoil conditions upon replacement. These soils have approximately 0.4 m of suitable subsoil below the topsoil. The C material has clay to heavy clay texture, massive structure and is very sticky and very plastic when wet or very hard when dry. Although non-sodic and non-saline, the C horizons

TABLE 3

Highvale Mine
Soil Suitability Criteria for Reclamation

Criterion	Unsuitable	Poor
pH	<4.5 or >8.5	8.0 - 8.5
SAR	>12	8 - 12
ESP	>15	10 - 15
EC mS/cm	>10	5 - 10
Saturation %	>120	80 - 120
Clay %	>60	40 - 60
Consistence[a]	Extremely Hard When Dry or Very Firm When Moist or Very Sticky and Very Plastic When Wet	Very Hard When Dry or Firm When Moist or Sticky and Plastic When Wet

If two suitability criteria in the following combinations are "poor" then a soil is also rated unsuitable.

Clay and Consistence
or Clay and SAR
or Clay and ESP
or Consistence and SAR
or Consistence and ESP

(a) Consistence as defined by CSSC, 1978.

Source: TransAlta Utilities Corporation. 1986. Highvale Mine - 1985 Development and Reclamation Plan are unsuitable due to very high clay content or a combination of clay and poor consistence.

Category 3 - Medium to Coarse Textured Luvisolic Soils (deep suitable). The B horizons are suitable subsoil due to sandy clay loam to silty clay loam textures, lack of sodicity and salinity and friable to firm consistence. The C horizons are also suitable as subsoil due to loamy sand to silty clay textures, massive to single grain structure, friable to firm consistence and lack of sodicity or salinity. These soils have at least 1.5 m of suitable subsoil.

Category 4 - Organic Soils (not rated). Organic soils have not been rated for reclamation suitability. These soils may be used as required as soil amendments.

Categories 2 and 3 have subsequently been refined to reflect differences in parent material thickness see section on Survey Data Integration).

Overburden Suitability Ratings. The same reclamation suitability rating system used for subsoils was used for overburden (Table 3). Each stratigraphic layer was rated for suitability.

Geographic Information System (GIS)

In order to handle the numerous possible permutations when summarizing information contained on the soil map a GIS was used. The system used was microcomputer based, using an IBM compatible microcomputer equipped with a 30Mb hard drive and color monitor (16 color). The GIS software is produced by TYDAC Technologies and is available under the name SPANS. The software allows for multiple (14) overlays of maps of various themes and produces a "unique conditions report" from these multiple overlays. The report can be imported into a spreadsheet environment where numerous sorts and data analyses are performed.

Survey Data Integration

Subsequent to the completion of the overburden and soil surveys it was evident that a method of integrating subsoil information from the two programs was necessary for reclamation and materials handling planning.

The soil survey information was applicable to the surface 1 to 1.5 m. The overburden programs describe the material below 1.5 m to coal. However, at many overburden dill holes soil material was also described and sampled as shallow as 0.8 m. The overlap of soils and overburden data for the 0.8 and 1.5 m depth required integration of the data. Correlation of soil parent material (C horizon) and overburden stratigraphic units required detailed review of field data and logs from both surveys (Monenco Ltd., 1987).

Soil Map Units and Stratigraphic Divisions. Cross sections, at 400 m intervals, were prepared for each pit. Soil polygon and inspection point data were compared to the information for the surface 1.5 m at each overburden drillhole. Direct comparisons were made between the nomenclature conventions used in the two programs. From these comparisons it was possible to develop a relationship between the soil parent materials and corresponding overburden stratigraphic layers. The combined information on subsoil suitability was used to determine the location and depth of suitable material for reclamation.

The integration of overburden soil information with soil survey information allowed refinement of the depths of suitable subsoil material for soils in Suitability Category 2 (shallow) and, particularly, Category 3 (deep). The Category 3 soils were defined as suitable to 1.5 m in the soil survey, but the overburden information confirmed the actual depths, which ranged from approximately 2 m to 7 m.

Suitability Maps. Three types of subsoil suitability depth maps were prepared. First, a computer generated isopach map based on overburden drillhole data. Second, a soil polygon map (ie. soil survey map) with portions of isopachs (based on overburden information) within polygons as appropriate. Third, a soil polygon map with the average depth of suitable subsoil indicated. The third map is used for short and long term mine planning. The original soil survey map comprised 26 soil units. The soil polygon map, with average suitable subsoil depths has been simplified to 11 map units with suitable subsoil thickness ranging from 0 to approximately 7 m.

Reclamation Targets

Agricultural Capability. Agricultural capability of the land prior to mining dictates reclamation targets since the capability of the reclaimed land is to be equivalent to that which existed prior to mining. The best agricultural land in the Highvale area is Class 3. There is no Class 1 and 2 land due to climate limitations. Agricultural capability (based on total for all pits) is: 22% Class 3; 36% Class 4; 33% Class 5; and 5% Class 6. The percentage of Class 3 land is similar in all Pits.

Subsoil Requirements. Subsoil is replaced on all levelled minespoil. Subsoil is replaced to a depth of 1.5 m over a total area the same size as the total Class 3 land prior to mining (i.e. 22%). All other area receive 0.35 m of subsoil.

Materials Handling Optimization

The subsoil suitability depth maps form the basis for subsoil salvage optimization studies. The objective of the subsoil optimization plan is to schedule the salvage and replacement of suitable subsoil taking into consideration the following:

1) Minimize subsoil haul distances.

2) Minimize double handling and stockpiling of subsoil by directly replacing subsoil when it is salvaged.

3) Confine the area of deep replacement (Class 3 agricultural capability) to one specific block.

4) Where possible, use primarily deep subsoils in the salvage operation

5) Utilize future pre-stripping truck/shovel operations advantageously to salvage subsoil.

Deep Subsoil Replacement. Deep (1.5 m) subsoil will generally be replaced in one block in each pit whenever possible. In order to optimize the placement of the deep subsoil block a number of thematic maps were examined, including maps showing the area of land made available for replacement on an annual basis as well as post-mine topography. The deep replacement block was optimally sited using the information generated by SPANS combined with criteria of: 1) maximum direct replacement; 2) minimum haul distance and 3) placement on near level or level areas.

Subsoil Salvage. Subsoil is salvaged annual immediately prior to mining. Salvage occurs only on an as needed basis. Direct replacement is the preferred method of subsoil salvage.

Volumes of suitable subsoil, available on an annual basis, were determined with SPANS by overlying the annual salvage mine plan on the suitable subsoil thickness map. By first determining the available volumes of suitable subsoil, adjustments in replacement requirements were made (by shifting the location of the deep replacement block) to take advantage of potential surpluses (maximize direct hauls) and avoid potential deficits (requiring stockpiling or longer hauls from more distance sources).

Results and Discussion

The primary result of combining soil survey and overburden survey information has been to refine the location (horizontal and vertical extent) and estimate of reserves of suitable subsoil material in each of the six mine pits. By refining the soil map information to include overburden thickness data, more accurate volume estimates were possible then would be made by using soil or overburden information alone.

By determining subsoil availability and replacement requirements early in the life of the mine it has become possible to selectivity handle suitable subsoil materials.

Mine planning exercies involve numerous iterations of alternative mine cut plans, resulting from changes in production scheduling or other factors. In the past each change in the mine plan resulted in time consuming and tedious recalculation of impacated areas (ie. recalculation of areas and volumes of disturbed soils). By digitizing the soil polygons and entering this information into a geographic information system with large and flexible attribute files and an excellent reporting system (unique conditions report) the type of information required can be generated quickly allowing for rapid comparisons of alternative mine plans. The GIS used allowed for easy importing of individual mine block/pit boundaries, another essential component in the data handling.

Alternative Uses of GIS Enhanced Data. To date we have used the GIS as a tool primarily to keep an exact aerial accounting of soil data on a digitized soil map base, combined with detailed mine plan information. This application is particularily useful for medium and long term planning.

The GIS is also extremely powerful tool in manipulating and presenting site specific data from the soil and overburden databases. For example, instead of using averages soil thickness, worked out for the entire mine area, specific information from individual drillholes or soil inspections can be reviewed or presented. This readily accessible data allows checking of average depths of suitable subsoil for specific map polygons and identification of areas where data may be difficient. For example, average depths for certain subsoils may be misleading if depths are highly variable (i.e. large standard deviation relative to the mean).

Summary

Computer databases and a GIS are only tools to enhance the basic data collected in the field. The individual field programs must be designed to collect sufficiently detailed information on the characteristics and extent of individual soils and overburden types.

Information from soil surveys and overburden surveys must be integrated to ensure maximum benefit of this information for mine planning and reclamation planning.

Optimizing the movement of large soil volumes is an essential element in mine reclamation planning. By combining the information from the integration study (soil/overburden) with alternate mine development plans, optimal soil handling plans can be developed. The use of a GIS in soil handling optimization studies significantly reduces the amount of the tedious and time consuming work. Optimization of salvage and replacement of suitable reclamation materials can significantly reduce the cost of materials handling.

Literature Cited

Alberta Soils Advisory Committee, Soil Quality Subcommittee. 1981. Proposed Soil Quality Criteria in Relation to Disturbance and Reclamation. Alberta Agriculture, Edmonton.

Brocke, L.K. 1977. The Canada Land Inventory Soil Capability for Agriculture in Alberta, Alberta Environment.

Canada Soil Survey Committee (CSSC), Subcommittee on Soil Classification. 1978. The Canadian system of soil classification. Can. Dep. Agric. Pub. 1646. Supply and Services Canada, Ottawa, Ontario. 164 pp.

Day, J.H. (ed). 1983. The Canada Soil Information System (CanSIS) Manual for describing soils in the field 1982 revised. L.R.R.I. Contribution No. 82-52. Research Branch, Agriculture Canada, Ottawa, Ontario.

McKeague, J.A. (ed). 1978. Manual on Soil Sampling and Methods of Analysis, 2nd edition, 1978. Canadian Society of Soil Science, Ottawa, Canada.

Monenco Limited. 1986. Highvale Soil Survey - 1985. Prepared for TransAlta Utilities Corporation, Calgary.

Monenco Limited. 1987. Integration of Highvale Soil and Overburden Data. Prepared for TransAlta Utilities Corporation, Calgary.

Schori, A. 1985. Land Reclamation. In Agrologist Vol. 14, No. 2. Agricultural Institute of Canada, Ottawa.

TransAlta Utilities Corporation. 1986. Highvale Mine - 1985 Development and Reclamation Plan. TransAlta Utilities Corporation, Calgary.